Revised New Biology Science Standards

Revision by Michael A. Clarke Ph.D. and Terry Hufford Ph.D. of the rearticulated standards adopted by the State Board of Education,
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High School Biology: Preamble

Chemistry of Living Things, Cell Biology, Genetics, Biological Evolution, Plant Biology, The Mammalian Body, and Ecosystems remain the fundamental principles of this rearticulation with the strands condensed to Cell Biology and Bio-Chemistry, Genetics and Evolution, Multicellular Organisms: Plants and Animals, and Ecosystems.
The standards are organized to create a construct of what is being taught and assessed as a content domain specific course in Biology. Where examples are listed it is not intended that these are exhaustive lists but should only be viewed as lists of exemplars to which teachers may add additional examples.

Scientific progress is made by asking relevant questions, conducting careful investigations, and drawing appropriate inferences based on observations and evidence. As a basis for understanding this concept, and to address the content in this domain, students should develop their own questions, perform investigations, and suggest appropriate inferences based on those investigations.

To demonstrate mastery of the common core science principals of Investigation and Inquiry, students should:

1. Demonstrate knowledge of the elements of scientific methodology: (a) Engage in making critical observations (b) Based on these observations develop an appropriate question or hypothesis (c) Perform investigations through experimentation (d) Collect data (e) Analyze the data (f) Formulate inferences or conclusions (g) Accept or reject original hypothesis (h) For rejected hypotheses propose a new hypothesis and repeat as necessary. Also, students should understand the limitations of any single scientific method (sequence of elements) in solving problems.

2. Know that in scientific investigations scientists cannot control all variables to obtain evidence. When they are unable to do so for ethical or practical reasons, they try to observe as wide a range of natural occurrences as possible so as to be able to discern patterns.

3. Be able to recognize the cumulative nature of scientific evidence and recognize the use and limitations of models and theories as scientific representations of reality.

4. Be able to distinguish between a conjecture (guess), a hypothesis, and a theory as these terms are used in science.

5. Have the opportunity to plan and conduct scientific investigations to explore biological phenomena, to verify previous results, to test predictions based on theories, and to discriminate between competing theories.

6. Be able to use hypotheses to design experiments so that appropriate data are collected and ensure meaningful interpretation of those data.

7. Be able to identify and communicate the sources of error (random and systematic) inherent in an experiment and be able to identify discrepant results and possible sources of error or uncontrolled variables. Students and instructors should be cautioned that variability is an important characteristic of natural populations and seemingly discrepant data points may be valid data points that are outliers [at either extreme of the distribution].

8. Be able to select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data. (The focus is on manual graphing, interpreting graphs, and mastery of metric measurements and units, with supplementary use of computers and electronic data gathering when appropriate).

9. Be able to formulate and revise explanations using logic and evidence, analyze situations, and solve problems that require combining concepts from more than one topic area of science within the domain being studied.

10. Be able to apply mathematical and statistical relationships involving linear and quadratic equations, simple trigonometric relationships, exponential growth and decay laws, and logarithmic relationships to scientific situations within each domain as appropriate.

11. Have the opportunity to observe natural phenomena and analyze their location, sequence, or time intervals (e.g., relative ages of fossil containing rocks and succession of species in an ecosystem).

12. Be able to explain that scientific discoveries can have both positive and negative implications, and the application of these discoveries will often involve decisions in other domains including economics, political science, ethics, sociology, and resources allocation.

13. Be able to recognize and consider the implications of statistical variability, reliability, and validity in experiments, and explain the need for controls in experiments

Biology Standards

STRAND 1	Cell Biology and Bio-Chemistry
Standard 1 Bio-Chemistry	Students should appreciate that Living things are made of atoms bonded together forming molecules, some of the most important of which are large and contain carbon (i.e., "organic" compounds). In order to demonstrate this appreciation students should be able to:
	B.1.1 Describe basic atomic structure using simplified Bohr diagrams to understand the basis of chemical bonding in covalent and ionic bonds. **B.1.2.** Describe the structure and unique properties of water and its importance to living things. **B.1.3.** Describe the central role of carbon in the chemistry of living things because of its ability to combine in many ways with itself and other elements. **B.1.4.** Know that living things are made of molecules largely consisting of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. **B.1. 5.** Know that living things have many different kinds of molecules, including small ones such as water; midsize ones such as sugars, amino acids, and nucleotides: and large ones such as starches, proteins, and DNA.
Standard 2 Cells	Students should know that all living things are composed of cells. In order to demonstrate this knowledge students should be able to:
	B.2.1. Describe that all organisms begin their life cycles as a single cell, and in multicellular organisms the products of mitosis of the original zygote form the embryonic body. **B.2.2.** Compare and contrast the general characteristics and constituents of prokaryotic and eukaryotic cells and their distinguishing features. One of the distinguishing characteristics between Prokaryotic and Eukaryotic cells is that Prokaryotic cells do not have a nucleus, and Eukaryotic cells do. Currently Biologists use a three Domain system [Archaea, Bacteria, Eukaryotes] for classifying living organisms. This three domain system replaces the older five kingdom system which consisted of the Prokaryotic kingdom (Archaebacteria and Eubacteria) and four Eukaryotic kingdoms (protista, fungi, plants, and animals). **B.2.3.** Demonstrate and explain that cell membranes act as highly differentially permeable barriers to penetration of substances by diffusive mechanisms or active transport. **B.2.4.** Explain that some structures in cells, such as mitochondria in most Eukaryotic cells (e.g., plants and animals), and chloroplasts in photosynthesizing organisms have apparently evolved by endosymbiosis (one organism living inside another, to the advantage of both). **B.2.5.** Describe that all growth and development of organisms is a consequence of biochemical activities taking place in the organism

	resulting in an increase in cell number, size, and/or products. **B.2.6.** Explain why communication and/or interaction are inherent between cells and within cells, and coordinate their diverse activities.
Standard 3 Reactions of Life	Students should know that all fundamental life processes of a cell are either chemical reactions or molecular interactions. In order to demonstrate this knowledge students should be able to:
	B.3.1. Observe and explain the role of enzymatic catalysis in biochemical processes. **B.3. 2.** Understand the function of cellular organelles and how the organelles work together in cellular activities (e.g., enzyme secretion from the pancreas). **B.3. 3.** Demonstrate that most cells function best within a narrow range of temperature and pH; extreme changes usually harm cells by modifying the structure of their macromolecules and, therefore, some of their functions. **B.3. 4.** Explain that complex interactions among the different kinds of molecules in the cell result in distinct cycles of activities, such as growth and division. **B.3. 5.** Explain how cell activity in a multicellular plant or animal can be affected by molecules from other parts of the organism. **B.3.6.** Explain the photosynthesis process: Plants make simple sugars and other molecules in their leaves and other chlorophyll-containing organs. The plants use carbon dioxide, water, and other inorganic materials, and using the energy of sunlight convert these to organic nutrients (food). **B.3. 7.** Recognize and describe that cellular respiration is an important process in the production of adenosine triphosphate (ATP), which is the basic energy source for cell metabolism.
Standard 4 Biological Structure and Organization	Students should have a clear understanding of the relationships between Biological Structure, Organization and how this impacts functionality. Specifically students should be able to:
	B.4.1. Explain the hierarchical organization of living things from least complex to most complex [subatomic, atomic, molecular, cellular, tissue, tissue systems (in plants), organs, organ systems (in animals), organism, population, community, ecosystem, and biosphere]. **B.4.2.** Observe and describe that within the cell are specialized parts involved in the transport of materials, energy capture and release, waste disposal, and motion of the whole cell or of its parts. **B.4.3.** Describe the organelles that plant and animal cells have in common (e. g., ribosomes, Golgi bodies, endoplasmic reticulum, and peroxysomes) and some that differ (e.g., only plant cells have chloroplasts, cell walls, a central vacuole, and glyoxysomes and only animal cells have lysosomes). **B.4.4.** Describe that the work of the cell is carried out by structures made up of many different types of large (macro) molecules that assemble biochemical compounds, such as proteins, carbohydrates,

	lipids, and nucleic acids. **B.4.5.** Explain that a complex network of proteins provides organization and shape to cells.
Standard 5 Chemical Change	Students should understand how Chemical Change impacts life. Specifically students should be able to:
	B.5.1. Explain how layers of energy-rich organic material, mostly of plant origin, have been gradually turned into great coal beds and oil pools by the pressure of the overlying Earth and its internal heat. **B.5.2.** Explain, using energy cycles and food webs, the significance of the impact of energy distribution on present day ecosystems [e.g., the impact of Global Warming on both aqua tic and terrestrial ecosystems].
STRAND 2	Genetics and Evolution
Standard 6 Theories of Inheritance	Students should be refining their understanding of Theories of Inheritance. Specifically students should be able to:
	B.6. 1. Research and explain how observations and the mathematical interpretation of inheritance patterns of certain characteristics by Gregor Mendel led to investigations of the mechanisms of inheritance. **B.6.2.** Investigate and describe how a biological classification system implies degrees of kinship between organisms or species can be deduced from the similarity of their nucleotide (DNA) or amino Acids (protein) sequences. Know that such systems may match the completely independent classification systems based on anatomical similarities. **B.6.3.** Explain how the actions associated with DNA and RNA, patterns of inheritance, and the reproduction of cells and organisms account for the continuity of life. **B.6.4.** Investigate and explain how molecular evidence reinforces and confirms the fossil, anatomical, behavioral, and embryological evidence for evolution, and provides additional detail about the sequence in which various lines of descent branched off from one another. **B.6.5.** Understand how Mendel's concepts of patterns of inheritance and Darwin's concept of natural selection have contributed to the current model of speciation and evolution.
Standard 7 Genetics	Students should know that entities contributing to inheritance are found both within and outside of chromosomes. An important component of this concept would be regions of DNA and/or RNA [traditionally called Genes - sets of information responsible for inheritance] which are encoded in the DNA of each organism. Students should understand that Genes are a logical not a physical construct though they may be related to a group of physical constructs. Specifically students should be able to:
	B.7.1. Explain how hereditary information is passed from parents to offspring on the chromosomes. Previously it was thought that in eukaryotes genes were contained in chromosomes. **B.7.2.** Explain how hereditary information may be passed from parents

	to offspring by non-chromosomal means. **B.7.3.** Describe how the discovery of the structure of DNA by James D. Watson and Francis Crick made it possible to interpret the genetic code on the basis of a nucleotide sequence. Know the important contribution of Rosalind Franklin's data to this discovery (i.e., the careful X-ray crystallography on DNA that provided Watson and Crick the clue they needed to build the correct structure). **B.7.4.** Know every species has its own characteristic DNA sequences. **B.7.5.** Explain how biological evolution is also supported by the discovery that the genetic code found in DNA is the same for almost all organisms. **B.7.6.** Differentiate between the functions of mitosis and meiosis. Mitosis is a process by which a cell divides into each of two daughter cells, each of which has the same number of chromosomes as the original cell. Meiosis is a process of cell division in organisms that reproduce sexually, during which the nucleus divides eventually into four nuclei, each of which contains half the original number of chromosomes. **B.7.7.** Explain how zygotes are produced in the fertilization process
Standard 8 Structure and Function of DNA	Students should know that DNA generally specifies the sequence of amino acids in proteins characteristic of that organism and how this impacts their functionality. Specifically students should be able to:
	B.8.1. Explain how the flow of information is usually from DNA to RNA then to protein. **B.8.2.** Explain how the genetic information in DNA molecules provides the basic form of instructions for assembling protein molecules and that this mechanism is the same for all DNA life forms. **B.8.3.** Understand and explain that specialization of cells is almost always due to different patterns of gene expression, rather than differences in the genes themselves.
Standard 9 Biodiversity	Students should understand Biodiversity as the result of genetic changes within a population. Specifically students should be able to:
	B.9.1. Understand and describe how inserting, deleting, or substituting short stretches of DNA [a physical construct] may alter a gene [a logical construct]. Recognize that changes (mutations) in the DNA sequence in or near a specific gene may (or may not) affect the sequence of amino acids in the encoded protein or the expression of the gene. **B.9.2.** Explain the mechanisms of genetic mutations and chromosomal recombinations, and when and how they are passed on to offspring. **B.9.3.** Explain how the sorting and recombination of genetic sequences in sexual reproduction result in a variety of potential allele combinations in the offspring of any two parents. **B.9.4.** Explain that genetic variation can occur from such processes as crossing over, transposition ['jumping genes'], deletion, and duplication of genetic sequences.

Standard 10 Evolution	Students should be cognizant of the Scientific Theories of the Origin of Life and the Evolution of Living Forms. Specifically students should be able to:
	B.10.1. Describe how life on Earth is thought to have begun as one or a few simple one-celled organisms about 3.5 billion years ago or more, and that during the first 2 billion years or so, only single-cell microorganisms existed. Know that, once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved. **B.10.2.** Explain that there was an earlier widely held belief that all known species had been created *de novo* at about the same time and had remained unchanged. Students should be able to explain that in the eighteenth century other ideas attributable to Georges-Louis Leclerc, Comte de Buffon, Jean Baptiste Pierre Antoine de Monet, Chevalier de Lamarck, and Erasmus Darwin led to a viable scientific mechanism for evolution embodied in a paper by Charles Darwin and Alfred Wallace. **B.10.3.** Research and explain that Darwin argued that only biologically inherited characteristics could be passed on to offspring, that some of these characteristics could be different from the average, they could be either advantageous or disadvantageous in survival and reproduction; and that over generations of time accumulation of the inherited advantages could lead to a new species. **B.10.4.** Explain that evolution builds on what already exists, so the more variety there is in a population, the greater species diversity will be in the future.
Standard 11 Environmental Impact on Evolution	Students should appreciate Evolution as the result of genetic characteristics that are influenced by changing environments. Specifically students should be able to:
	B.11.1. Explain how a large amount of diversity within a population increases the chance that certain members of the population will survive. **B.11.2.** Explain how a large diversity of species increases the chance that at least some living things will survive in the face of large or even catastrophic changes in the environment. **B.11.3.** Research and explain how natural selection provides a mechanism for evolution and leads to populations of organisms that are suited for survival in particular environments. **B.11.4.** Explain that biological diversity, episodic speciation, and mass extinction can be understood by examination of the fossil record, comparative anatomy, biochemistry, and other evidence.
STRAND 3	Multicellular Organisms: Plants and Animals
Standard 12 The Plant Kingdom	Students should be aware of the unique Biology of The Plant Kingdom. Specifically students should be able to:

	B.12. 1. Describe the structure and function of roots, leaves, flowers, and stems of plants. **B.12.2.** Know that the great diversity of species of flowering plants can be associated with animal diversity, and pollinating agents. **B.12.3.** Explain that during the process of photosynthesis, plants produce oxygen which may be released into their environment [air or water]. **B.12.4.** Recognize that plants have evolved numerous mechanisms which result in their ability to survive in "unpredictable or unfavorable environments."
Standard 13 Plant and Animal Interactions	Students should develop an understanding of Plant and Animal Interactions and be aware that Plants are essential to Animal life on Earth. Specifically students should be able to:
	B.13.1. Identify the roles of plants in the ecosystem: Plants make food, release oxygen, provide habitats for animals, and contribute to the production of soil and the prevention of erosion. In addition they provide thousands of useful products for people (e.g., energy, medicines, paper, and resins). **B.13.2.** Describe that plants have broad patterns of behavior that have evolved ensuring reproductive success. Co-evolution with animals and insects has resulted in mechanisms that effectively and efficiently distribute a plant's pollen and seeds.
Standard 14 Mammals	Students should understand the nature and interaction of biological Systems in the mammalian Body. Specifically students should be able to:
	B.14.1. Consider and explain the major systems of the mammalian body (digestive, respiratory, circulatory, excretory, nervous, endocrine, integumentary, immune, skeletal, and muscular) and how they interact with each other.
Standard 15 Homeostasis	Students should consider the significance of Homeostasis in the Mammalian Body. This can be understood as a result of the coordinated structures and functions of organ systems. The internal environment of the mammalian body remains relatively stable (homeostatic), despite changes in the outside environment. Specifically students should be able to:
	B.15.1. Analyze the complementary activity of major body systems, such as how the respiratory and circulatory systems provide cells with oxygen and nutrients, and remove toxic waste products such as carbon dioxide. **B.15.2.** Explain how the nervous system mediates communication between different parts of the body and the environment. **B.15.3.** Describe that the nervous and endocrine systems maintain overall regulation of functional conditions within the body by chemical communication. **B.15.4.** Investigate and cite specific examples of how the mammalian immune system is designed such that it protects against microscopic organisms and foreign (or nonself) substances from outside the body and against some aberrant (e.g., cancer) cells that arise within.

STRAND 4	Ecosystems
Standard 16 Classification of Systems	Students should understand Classification in Ecological systems. Specifically students should be able to:
	B.16.1. Using ecological studies, explain distinct relationships [commonalities and differences] between urban environments and other environmental systems
Standard 17 Dynamics of Ecosystems	Students should understand Ecosystems as dynamic systems. Specifically students should be able to:
	B.17. 1. Illustrate and describe both cyclic and non-cyclic biotic and abiotic factors (matter, nutrients, energy) of an ecosystem. **B.17.2.** Describe how factors in an ecosystem, such as the availability of food, water, oxygen, and minerals, and the ability to recycle the residue of dead organic materials, cause fluctuations in population sizes. **B.17. 3.** Explore and explain how changes in population size have an impact on the ecological balance of a community and how the effect of that impact can be analyzed. **B.17.4.** Describe how the physical or chemical environment may influence the rate, extent, and nature of the way organisms develop within ecosystems.
Standard 18 Stability of Dynamic Systems	Students should understand that ecosystems may have inherent stability or instability and either can result in the development of a system in dynamic equilibrium. Specifically students should be able to:
	B.18.1. Describe how ecosystems can be reasonably stable over hundreds or thousands of years. **B.18.2.** Explain that ecosystems tend to have cyclic fluctuations around a state of rough equilibrium, and change results from shifts in climate, natural causes, human activity, or when a new species or invasive species appears.
Standard 19 Pollution	Students should understand the effects of Pollution and other Environmental challenges and their long term consequences. Specifically students should be able to:
	B.19.1. Consider the differences between point and non-point source pollution: Investigate and describe how these can affect the health of a bay's watershed and wetlands. **B.19.2.** Assess the method for monitoring and safeguarding water quality, including local waterways such as the Anacostia and Potomac rivers, and know that micro invertebrates, protista, and bacteria can be early warning signs of decreasing water quality.